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Title

“The management of small area burns and unexpected post-burn illness in children under five years of age – a costing study in the English healthcare setting”

Author names and affiliations

R.Kandiyali^{a,b}, J. H. Sarginson^{b,c}, L. Hollén^{a,b}, F. Spickett-Jones^b and A.E.R. Young^b

^a Centre for Child and Adolescent Health, School of Social and Community Medicine, Oakfield Grove, BS8 2BN.

^b The Scar Free Foundation Centre for Children’s Burns Research, The Bristol Royal Hospital for Children, Bristol, BS2 8BJ.

^c Department of Plastic and Reconstructive Surgery, Southmead Hospital, North Bristol NHS Trust, Bristol, BS10 5NB.

Corresponding author

rebecca.kandiyali@bristol.ac.uk

Abstract

The objective of this economic study was to evaluate the resource use and cost associated with the management of small area burn injuries, including the additional costs associated with unexpected post-burn illness in children of less than five years of age. This study was conducted as a secondary analysis of a multi-centre prospective observational cohort study investigating the physiological response to burn injury in children. 452 children were included in the economic analysis (median age=1.60 years, 61.3% boys, median total burn surface area [TBSA] =1.00%) with a mean length of stay of 0.69 days. Of these children, 21.5% re-presented to medical care with an unexpected illness within fourteen days of injury.

The cost of managing a burn of less than 10% TBSA in a child less than five years of age was £785. The additional cost associated with the management of post-burn illness was £1,381. A generalised linear regression model was used to determine the association between an unexpected post-burn illness, presenting child characteristics and NHS cost. Our findings may be of value to those planning economic evaluations of novel technologies in burn care.

Keywords

Pediatric Burn, Post-burn illness, Cost, Cost analysis

Abbreviations

TBSA, Total Burn Surface Area; PICU, Paediatric Intensive Care Unit; HDU, High Dependency Unit; TSS, Toxic Shock Syndrome; TSSLI, Toxic Shock Syndrome-Like Illness; ED, Emergency Department; MIU, Minor Injury Unit.

Introduction

Burns are the third most common injury type sustained by children of less than five years of age in England. [1] In 2015, over 7000 children under the age of five required admission to hospital for management of burn injuries. [2] Children of less than five years of age with burns of less than 10% of the total body surface area (TBSA) comprise 70% of the caseload of specialist paediatric burn services in the UK. [3, 4]

Children of this age, despite having burns of small surface area, can become systemically unwell whilst the burn is healing. Up to 25% of children less than five years of age with burns of less than 10% TBSA have been shown to re-present to medical care facilities with an unexpected post-burn illness within fourteen days of injury, and up to 10% require re-admission to hospital. [5] Potential causes include; a systemic inflammatory response to the injury [6, 7], community acquired viral illness [8, 9], burn wound infection [10, 11], systemic bacterial infection [10, 12], and toxic shock syndrome [13, 14].

Sources of additional economic burden arising from unexpected post-burn illness following the initial management of the burn injury include:

- i. Healthcare resource use including; use of primary care /emergency department /walk in centre services, inpatient care, outpatient care, theatre time, medications and dressings.
- ii. Family resource use such as; increased time off work (and also lost leisure time), travel to hospital or appointments, use of hotel or temporary accommodation near a hospital and extra childcare.

Although there have been studies previously published on inpatient costs associated with the management of burn injury in children [15-18], this literature is limited to small patient populations (single-centre studies) or health care systems with insurance based coverage. Furthermore, economic studies for the management of burn injury originating from outside England may not be generalisable

due to fundamental differences in the way healthcare is delivered, financed and reimbursed between continents, countries and the devolved nations of the UK [19] In addition, no study to date has focussed on the additional costs associated with the management of post-burn illness. This information will be useful to those planning cost-effectiveness studies in diagnostic and therapeutic technologies that target post-burn infection.

The principal aim of this study was to identify the additional cost associated the unexpected re-presentation of a child of less than five years of age to a GP, local hospital or burns service within fourteen days of sustaining a small area burn injury (i.e. source i. of the additional economic burden as stated above). Family resource use will not be discussed in this paper.

Methods

This economic study was nested in the MISTIC (Morbidity in Small Thermal Injury in Children) study; a prospective observational cohort study looking at the physiological response to burn injury in children less than five years of age with burns of less than 10% TBSA. [5] Recruitment was conducted at three burns services in England between January 2014 and July 2015: The South West Children's Burns Centre at the Bristol Royal Hospital for Children; The Burns Centre at Birmingham Children's Hospital and the St Andrews Centre for Plastic Surgery and Burns in Chelmsford. Children were identified and recruited prospectively on presentation to the burn centre with an acute burn injury. Children were eligible if they: were greater than 28 days old and less than five years old at the time of the injury, had sustained a burn of less than 10% TBSA of any depth from any mechanism and presented to the recruiting burn service within 48 hours of injury.

Data collection

Background and clinical data were obtained through interrogation of the medical notes and from a parental questionnaire completed at the time of initial presentation of their child with an acute burn injury. Recorded details included; demographics (age and sex) and details of the injury (burn type, site, size (%TBSA) and depth). For the purpose of this study, burn depth was described as the burn injury either having or not having any deep dermal or full thickness component. A deep dermal or full thickness component was identified if this was documented in the child's notes by a senior clinician, or if the child had a skin grafting procedure. Burn type was coded as either scald, contact burn or other, where other included flame, chemical, or electrical burn and sunburn. Data were also collected on any unexpected illness experienced by the child within fourteen days of burn injury. Recorded details included; the location of re-presentation for medical review (GP, local hospital or the burns service), the reported symptoms and signs, and the clinical diagnosis given by the treating clinician.

Patient National Health Service (NHS) tertiary, secondary and primary care resource use was recorded following interrogation of the medical notes with additional information from a further parental questionnaire completed at six weeks following injury. Recorded details included: length of stay (initial presentation, admission and re-admission), admission to PICU and HDU, trips to theatre, use of antibiotics, units of fresh frozen plasma used and the number of outreach, outpatient, ED and GP consultations up to six weeks post injury. The perspective of this study, and the associated costings, was that of National Health Service England (NHS England).

Valuation of resources

We estimated the mean NHS costs per patient applying a 2014/15 price year. No adjustment to prices (i.e. 'discounting') [20] was required as this study examined the cost over an acute six week period.

Costs were assigned to each resource item and combined with information on the price of units to estimate costs. The 'excess bed-day cost' associated with paediatric minor injury was used to value

the marginal cost of an additional day on the ward following initial burn management. [21] Other unit costs were from publicly available sources (see Table 1).

<Table 1. Unit costs associated with the management of paediatric burns injury patients>

Statistical Analysis

Due to the skewed nature of cost data, we used non-parametric bootstrap methods (1000 replicates) to compute the bias corrected mean additional cost and intervals associated with post-burn illness. Cost data is invariably skewed and the bootstrap method, which is based on sampling with replacement from the original data, does not require parametric assumptions and is an accepted technique. [22, 23]

We used regression methods (generalized linear model, GLM) to consider the additional cost of a re-presentation with unexpected post-burn illness, controlling for patient (age, sex) and injury characteristics such as type (contact, scald or other), depth (as determined by the documented report of a deep dermal or full thickness component), and burn size. Our modelling approach suggested that the gamma distribution with log link function best fitted the data.

We compared output from the multivariable model with the univariate analysis obtained via non-parametric bootstrapping.

Results

The MISTIC study recruited 625 children. Full clinical follow-up, including whether or not the child experienced any unexpected illness within fourteen days of injury, was achieved for 476 children (76%). Sufficient data on NHS resource use to enable a costing analysis was obtained for 452 of the children.

Of these 452 children, ninety-seven (21.5%) re-presented with an unexpected illness within fourteen days of injury. Children re-presented with a range of symptoms including; a high temperature, vomiting, rash, lethargy, cough/cold and 'non-specifically unwell'. Children were treated for a range of clinical diagnoses including; viral illness, burn wound infection, deep burn (inflammatory response), and toxic shock syndrome-like illness (TSSLI) [A clinical diagnosis of TSSLI was given in cases where there was a suspicion of TSS based on the presenting symptoms and signs, regardless of whether or not the patient went on to exhibit all features of TSS to enable a confirmed diagnosis using the US CDC criteria] [24]. Thirty-eight children required re-admission for management of their post-burn symptoms. Seven children were treated in critical care (PICU or HDU) for their post-burn re-presentation.

Patient Demographics

<Table 2. Patient demographics for patients with available cost data>

The patient demographics are presented in Table 2. The majority of burns were very small in area (median: 1.0, IQR: 0.3-2.5) and there were more scalds than contact burns (57.1 vs. 39.6%), with low incidences of other non-contact burns (3.3%). Univariate analyses suggested that presenting characteristics: age, size, type and burn depth (as evidence by a full thickness or dermal component) showed significant differences between children who re-presented with an unexpected post-burn illness and those that did not. The children who re-presented were younger in age, had larger surface area burns, more frequently had a deep component to the injury, and the injury was more likely to be from a scald (Table 2).

Healthcare resource use associated with post-burn illness

Table 3 describes the NHS England resource use and costs (from within tertiary, secondary and primary care) associated with the management of both the children who did not re-present and the children who re-presented with an unexpected post-burn illness. The mean length of stay (including any readmissions) was 0.56 days (SD: 2.23) in children who did not re-present, and 2.14 days (SD: 2.58) in children that did re-present (Table 3). Of the children who re-presented with an unexpected post-burn illness, 35% received antibiotics, 12% returned to theatre for further management of the burn wound and 9% received fresh frozen plasma for management of TSSLI.

<Table 3. Mean per patient units of resource and costs associated with a small paediatric burn>

Total costs associated with burn injury

The total average healthcare cost of managing a burn injury over the six week period post-injury for a child who did not re-present for medical review was £785 (Table 3). For a child who re-presented with an unexpected post-burn illness, this estimate was £2,166. The inpatient costs were much higher for children who did re-present with an unexpected post-burn illness (Table 3). A particularly important cost driver for children who re-presented unwell was an admission to critical care (HDU or PICU), which accounted for 18% of length of stay costs overall.

Adjustment for presenting covariates

We used multivariable regression (using a generalised linear model with a gamma family and log link) in order to explore the association between the child's presenting characteristics (age, sex, TBSA, type of injury and depth of the burn) and costs. Results from both the univariate and multivariable models suggested that burns with a deep dermal or full thickness component and larger TBSA were associated with significantly higher costs. Adjustment for presenting characteristics suggested that the cost ratio

- the multiple by which costs are higher when other covariates were adjusted for - following a readmission was 2.02 (Table 4).

<Table 4. Estimated cost ratios from multivariable regression analysis>

Discussion

Resource use information was collected prospectively on a cohort of 452 children under five years of age with burns of less than 10% TBSA. In total, 97 children re-presented with an unexpected post-burn illness. Thirty-eight of these children were re-admitted to hospital, and seven children required treatment in a critical care setting.

In our analysis the major cost driver in terms of contribution to total costs in the acute phase of injury was related to inpatient bed days. While it is difficult to compare costs across different health care systems, total length of stay appears similar to that reported in paediatric burn populations elsewhere with similar burn sizes. [15, 25] The next most significant cost driver was re-presentation to the burns service or an emergency or urgent care services (i.e. ED and MIU visits). Overall, children who re-presented because of unexpected post-burn illness were twice as expensive to treat as those that did not.

There are several limitations to our study. Firstly, this study was conducted at three tertiary burns services in England. The provision of burns care, and - foreseeably the rate of representations - may differ in other burn services in the UK, including under services operated by NHS Scotland or Wales, and in instances where a child's initial management is in primary or secondary care. Our study includes children who re-presented to local primary/secondary care services and who were managed by them, in addition to re-presentations to the burn service.

Secondly we note that the most comprehensive approach ("micro-costing") to detail resource use in a study of burn injury would include the number and frequency of all dressings, medications and anaesthesia as well as staff time relating to clinician contact and procedures. We did not plan this

study as a micro-costing exercise, and therefore anticipate that our estimates might be different from studies employing such approaches. While we recognise that micro-costing methods provide a more comprehensive description of cost categories, we nevertheless present resource use and unit costs separately, aiding transparency and in line with commonly agreed standards of best practice. [26, 27] We have a sample size of 452 patients, and high completion rates. Micro-costing approaches have tended to be based on much smaller sample sizes and therefore often do not achieve significance. Additionally, micro-costing approaches may be more susceptible to local variations in practice as they tend to be grounded in direct observations and/or exploitation of trust financial systems. In contrast, our national sources of unit cost information are based on activity and spell data from NHS trusts nationally and nationally available inventories of unit costs.

Additionally, we note that this analysis presents results and confidence intervals based on skewed cost data. To adjust for presenting covariates, we selected a relatively simple model based on the inspection of the distribution and model diagnostics. [28] A more complex model may possibly offer superior fit, but such methods are technical and perhaps lend themselves less to intuitive explanation. [29]

Furthermore, we note this study does not present information on the rate of community acquired infection in a control group without burn injury and therefore it is plausible that some of the TSSLI may be accounted for by incidence of community acquired viral infections. Future studies need to consider if this issue can be dealt with by the selection of an appropriate control group.

This study focussed on children under 5 with burns of less than 10% TBSA as this group represents the majority of the caseload of paediatric burn services. However, larger burns are likely to incur much higher costs, and post-burn illness in children with larger burns may also incur greater additional costs. The costs in larger burns cannot be simply extrapolated from this study, as larger burns are much more resource intensive. This would need to be explored in a future study. Post-burn illness also has implications for the child's recovery and outcome with associated cost implications that extend into

the longer term. Post-burn infection may increase healing time. Prolonged healing is associated with an increased risk of scarring. [30] Further research might focus on the costs of the sequelae of burn injury (i.e. including the costs of scar management services) by using a longer period of follow-up.

Additionally family costs, such as the costs associated with travel, family accommodation, and out of pocket expenses might be explored. Information on these costs will provide a more comprehensive profile of the potential for cost-savings from innovations in burn care, which might be used in future economic evaluations. Such evaluations (most commonly 'cost-effectiveness analyses') are often required by healthcare funders to assess innovations in burn care. If cost-effective, these innovations are often recommended for funding. In this way, this research is part of a bigger 'priority setting' picture which is not just focussed on cost, but on patient benefit too.

Conclusions

This study demonstrates the high healthcare costs of managing small burn injuries, and the additional costs of managing unexpected post-burn illness, with our model predicting a doubling of the acute care costs associated with a re-presentation. Additionally our study shows that secondary analysis of data using observational study data can be an efficient method of addressing an evidence gap with important implications regarding the future of burn care. Research should now consider the sequelae of post burn illness over the longer term.

Conflict of interest: none

Contributors: JS, RK and AY had the original idea for the secondary analysis. JS designed the MISTIC study and collected the data with guidance from AY. JS, FSJ and AY advised on costing assumptions. RK did the analysis. LH provided statistical input and expertise. All authors were responsible for drafting and revising the manuscript for important content and approving the final version.

Acknowledgements

The MISTIC study was conducted in accordance with the Declaration of Helsinki (2008) and adhered to the principles outlined in the NHS Research Governance Framework for Health and Social Care (2nd Edition). NHS ethics approval was sought for the study, and was granted on the 2nd December 2013 (NRES Committee South West - Exeter: 13/SW/0306).

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